

REVERSIBILITY OF SINGLE-INCENTIVE SELECTIVE ASSOCIATIONS

LEIGH V. PANLILIO AND STANLEY J. WEISS

THE AMERICAN UNIVERSITY

Rats were trained to press a lever in the presence of a tone-light compound stimulus and not to press in its absence. In each of two experiments, schedules were designed to make the compound a conditioned punisher for one group and a conditioned reinforcer for the other. In Experiment 1, one group's responding produced food in the presence of the compound but not in its absence. The other group's responding terminated the compound stimulus, and food was presented only in its absence. When tone and light were later presented separately, light controlled more responding than did tone in the former group, but tone gained substantial control in the latter. The same effects were also observed within subjects when the training schedules were switched over groups. In Experiment 2, two groups avoided shock in the presence of the compound stimulus. In the absence of the compound, one group was not shocked, and the other received both response-independent and response-produced shock. When tone and light were presented separately, the former group's responding was mainly controlled by tone, but the latter group's responding was almost exclusively controlled by light. These effects were also observed within subjects when the training schedules were switched over groups. Thus, these single-incentive selective association effects (appetitive in Experiment 1 and aversive in Experiment 2) were completely reversible. The schedules in which the compound should have been a conditioned reinforcer consistently produced visual control, and auditory control increased when the compound should have become a conditioned punisher. Currently accepted accounts of selective associations based on affinities between shock and auditory stimuli and between food and visual stimuli (i.e., stimulus-reinforcer interactions) do not adequately address these results. The contingencies of reinforcement most recently associated with the compound and with its absence, rather than the nature of the reinforcer, determined whether auditory or visual stimulus control developed.

Key words: selective associations, stimulus salience, biological constraints on conditioning, stimulus-reinforcer interactions, stimulus control, avoidance, appetitive conditioning, lever press, rats

Selective associations are demonstrated when discriminative or conditioned stimuli of different sensory modalities vary in effectiveness as a function of conditioning context. The first accounts of these effects (Foree & LoLordo, 1973; Garcia & Koelling, 1966) described affinities between stimulus modalities and specific reinforcers, using terms like *stimulus-reinforcer interactions* or *cue-to-consequence specificity* to describe the phenomena. For example, auditory stimuli demonstrated stronger control of shock-avoidance responding, but visual stimuli were dominant when responding produced food. This was true for both pigeons (Foree & LoLordo, 1973) and rats (Schindler & Weiss, 1982). However, the recent "single-incentive selective association" experiments of Weiss, Panlilio, and Schindler (1993a, 1993b) have demonstrated that both food and shock schedules are capable of producing either vi-

sual or auditory stimulus control, suggesting that food and shock per se do not determine whether control is primarily auditory or visual.

The selective association experiments in this laboratory have all utilized an experimental paradigm in which rats are trained to press a lever in the presence of a tone-light compound stimulus (TL) and to cease responding in its absence (TL̄). Following this training, the tone and the light are presented separately in a stimulus-element test to determine the degree to which the auditory and visual modalities control responding. Schindler and Weiss (1982) used this basic procedure to replicate with rats on free-operant schedules the stimulus-reinforcer interaction demonstrated by Foree and LoLordo (1973) with pigeons on discrete-trials schedules. When rats' responding produced food during TL, light controlled high rates of responding during the stimulus-element test, but few responses were emitted in the presence of the tone. In contrast, when rats avoided shock during TL, tone controlled substantial rates of responding during the test. Further investigation demonstrated that this effect could be reversed. Rats originally trained on the shock-avoidance schedule were switched to the

This research was supported by National Institute of Mental Health Research Grant MH-45545 awarded to the second author. It was presented at the 1991 meeting of the Psychonomic Society in San Francisco. Reprints may be requested from Stanley J. Weiss, Department of Psychology, The American University, Washington, DC 20016.

food-reinforcement schedule, and rats originally trained on the food schedule were switched to the shock-avoidance schedule. Again, training with food produced mainly visual control, and training with shock increased auditory control.

Although the dominant sensory modality appeared to be determined by the reinforcer most recently associated with TL, it was not clear that the physical qualities of food and shock directly determined whether auditory or visual control developed. Besides their different sensory characteristics, food and shock represent different classes of unconditioned stimuli (appetitive and aversive, respectively) that have disparate effects on operant behavior (reinforcing and punishing, respectively). These positive and negative hedonic values can also be conditioned to a discriminative stimulus that may reinforce or punish a response that produces it (as in the observing response paradigm; see review by Dinsmoor, 1983). In the food schedule used by Schindler and Weiss (1982), TL may have gained positively reinforcing properties because it was associated with food reinforcement, but $\overline{\text{TL}}$ would not (Auge, 1974; Kendall & Gibson, 1965). In the shock schedule, TL may have gained aversive properties because it was associated with shock avoidance, whereas $\overline{\text{TL}}$ was shock free (Culbertson & Badia, 1973; Michael, 1982). Therefore, in the Schindler and Weiss (1982) study, the hedonic value conditioned to TL was confounded with the physical properties of food and shock. This led Weiss et al. (1993a) to suggest that the hedonic value of TL may have determined the dominant modality of stimulus control, independently of whether food presentation or shock avoidance ultimately maintained responding.

Recent experiments have supported this hypothesis by breaking the confounding effects between the physical nature of the unconditioned stimulus or reinforcer ultimately maintaining responding and the hedonic value conditioned to TL. To demonstrate single-incentive selective associations, all rats were trained with the same primary reinforcer, but contingencies were manipulated to vary the hedonic value conditioned to the TL discriminative stimulus. Weiss et al. (1993a) used this approach to produce either auditory or visual stimulus control with schedules of food presentation designed to make TL a conditioned

punisher or reinforcer, respectively. Schedules of shock presentation also produced either visual or auditory stimulus control, depending on whether TL was more or less aversive, respectively, than $\overline{\text{TL}}$ (Weiss et al., 1993b). These results necessitate a reevaluation of the term *stimulus-reinforcer interaction* and the premise that the nature of the reinforcer directly determines the dominant modality of stimulus control.

As mentioned above, Schindler and Weiss (1982) found that the dominant modality of stimulus control, established with their food or shock schedule, could be reversed by training with the other schedule. Thus, the stimulus-reinforcer interaction could be produced both between and within groups. The single-incentive selective associations have been demonstrated only in between-groups comparisons. The goal of the current experiments was to determine whether these effects are reversible by attempting to demonstrate them with a within-subject design. To do this, rats originally trained in the experiment of Weiss et al. (1993b) with schedules that produced either auditory or visual stimulus control were trained with different schedules in the present study. Rats originally trained with food continued to receive food in the reversal phase, and rats originally trained with shock continued to receive shock. However, the reversal schedules were designed to condition a hedonic value to a TL discriminative stimulus opposite to that in the original phase. Experiment 1 tested the reversibility of the appetitive selection association using only food-maintained responding, and Experiment 2 evaluated the aversive case using only shock-avoidance responding.

EXPERIMENT 1

The demonstration of single-incentive selective associations involves maintaining responding in each group of animals with the same primary reinforcer, but manipulating the contingencies operating in TL and $\overline{\text{TL}}$ to vary the relative hedonic value of TL. Weiss et al. (1993a) compared rats trained on a multiple schedule in which all food was received in TL to rats trained on a chained schedule in which all food was received in $\overline{\text{TL}}$. Thus, TL would have gained properties of a positive reinforcer in the former case but not in the latter. In the multiple variable-interval extinction schedule

(mult VI EXT), lever pressing in TL produced food on a VI schedule. During TL, no food was delivered and responding had no programmed consequences (extinction). In the chained variable-interval differential-reinforcement-of-other-behavior schedule (chain VI DRO), the only effect of responding during TL was to produce the TL component, during which food was presented when a certain amount of time passed without a response. The chain VI DRO schedule created auditory stimulus control that had previously been seen only after aversive training (with shock avoidance in TL).

Experiment 1 determined whether switching the appetitive training schedules (mult VI EXT and chain VI DRO) could reverse the established modality of stimulus control. In the previous demonstration of a reversible selective association (Schindler & Weiss, 1982), rats responded on a VI food schedule in one phase of the experiment and a shock avoidance schedule in the other. To the extent that two food schedules appear to be less different than a food schedule and a shock schedule, a reversal of stimulus control could be more difficult in the single-incentive experiment. Although the food schedules used in Experiment 1 clearly produced different stimulus control in naive rats (Weiss et al., 1993a, 1993b), it could not be taken for granted that once auditory or visual control was established, this dominance would reverse when the schedules were switched. Although it is typical for response patterns to adjust to changes in contingencies, such changes do not always affect the relative control by elements of a compound discriminative or conditioned stimulus. For example, pretraining with one element of a compound stimulus may enhance or retard the acquisition of control by other elements in later stages of training (Mackintosh, 1977). In previous experiments using a blocking procedure (Kamin, 1969), pretraining with the less "relevant" stimulus did not alter the stimulus-reinforcer interaction effect in pigeons (LoLordo, Jacobs, & Foree, 1982), but prevented it in rats (Schindler & Weiss, 1985). This suggests a tendency for an established discriminative stimulus to maintain control of responding in rats despite the influence of factors responsible for selective associations. A within-subject demonstration of the appetitive single-incentive selective association would therefore represent the most

vigorous demonstration yet of the power of these schedules to determine the modality of stimulus control.

METHOD

Subjects

Sixteen experimentally naive male Long-Evans hooded rats of approximately 3 months of age were housed in individual cages in a continuously lit colony room with free access to water, except during training sessions. Weights were maintained at approximately 80% of ad lib through supplemental feedings of laboratory chow following daily training sessions, or around 3:00 p.m. on days when training sessions were not conducted. Two rats were dropped from the mult VI EXT group. One experienced an equipment malfunction, and the other failed to develop stable responding on the VI schedule prior to discrimination training. Results of the first phase of training, prior to the schedule reversals, were presented as group data by Weiss et al. (1993b).

Apparatus

Three identical operant conditioning chambers (Weiss & Schindler, 1989) were enclosed in sound-attenuation chests (Weiss, 1970). Experimental events were controlled by computer from an adjacent room, where cumulative recorders were also situated. Each chamber measured 20 cm high, 23 cm long, and 18 cm wide, and was dimly lighted at all times by a shielded 7.5-W houselight operated at 3 W. The level of illumination created by this houselight was enough to make the rat barely discernible, but did not activate a photometer (Simpson 408-2). A Gerbrands lever manipulandum and food trough were situated on the front wall, close to the right and left walls, respectively. A response on the lever closed a microswitch, requiring a force of 0.14 to 0.18 N. Noyes 45-mg food pellets were delivered to the trough by a Gerbrands feeder (Model D). Ambient noise was measured at 70 dB (Realistic SPL meter, aimed at the front wall directly above the lever). A 2000-Hz, 79-dB tone was generated by a BRS AO-201 audio oscillator, amplified by a BRS AA-201 amplifier, and presented through an 8- Ω , 20-cm speaker mounted in an enclosure 21.5 cm above the training chamber. There were two 15-cm, 25-W, 120-V tubular light bulbs 10 cm behind the two translucent side walls that provided

the visual stimulus. These lights were operated at 74 V and produced 0.55 log footlamberts at the center of a side wall.

Procedure

The goal of all training schedules was for the rats to press the lever at a moderate rate in the presence of the tone-light compound stimulus (TL) and to cease responding in the absence of the compound ($\overline{\text{TL}}$). The parameters of the individual schedules were gradually adjusted over sessions to approximate their final values. Each rat was trained for 5 to 7 days per week, with sessions lasting about 2 hr or until 100 food pellets had been delivered. The training criteria and stimulus-element test were the same for both schedules. Once the criteria were met, the test was given. Following training and testing under one schedule, a rat was trained and tested under the other schedule and tested again.

Original training under mult VI EXT. During the first training session, rats were magazine trained. TL was present for the entire session. Food pellets were delivered on a variable-time (VT) 2-min schedule. The session ended when 45 pellets had been delivered.

Next, the rats learned to press the lever on a continuous reinforcement (CRF) schedule in TL. Response-independent food presentation was continued on a VT 2.5-min schedule, but food was also presented immediately if the lever was pressed. Once the lever had been pressed seven times, response-independent delivery was discontinued. This session ended after the delivery of about 100 pellets.

Starting with the third session, discrimination training began. A mult CRF EXT schedule was in effect, in which each lever press during TL produced a pellet. During $\overline{\text{TL}}$, no food was presented, and a response-correction contingency was in effect to reduce responding. Thus, responding within the last 10 s scheduled for the $\overline{\text{TL}}$ component delayed the presentation of TL until 10 s (the response-correction value) had passed without a response. Components were scheduled to alternate every 30 to 60 s.

In the sessions that followed, a VI schedule operated in TL. The mean interval increased over sessions, with values of 15, 22, 30, 45, and 60 s. For the VI 60-s schedule, the intervals ranged from 3 to 228 s and were drawn in order from a list (entered at a random point

at the start of each session) in which the duration of an interval was independent of the duration of the preceding interval. The VI values for other schedules were mathematically derived from the VI 60-s list. The value of the VI was increased when the cumulative record revealed that a rat had responded at a steady rate for approximately three sessions. The response-correction values increased along with the VI value according to the series 10, 15, 20, 25, and 30 s. Under the final parameters of the mult VI EXT schedule, component durations were drawn randomly, without replacement, from a list with a mean of 60 s (range, 30 to 120 s). Component durations for earlier sessions were mathematically derived from the same list and were approximately equal to the VI value.

Original training under chain VI DRO. Magazine training for the chain VI DRO schedule was the same as for mult VI EXT, except that for 3 s preceding and 15 s following pellet delivery, $\overline{\text{TL}}$ was presented. During the next session, this response-independent food delivery continued, but lever presses during TL were immediately followed by $\overline{\text{TL}}$, in the presence of which food was delivered according to a DRO contingency. That is, food delivery was delayed until 3 s had passed without a response. During this session, one pellet per $\overline{\text{TL}}$ presentation was delivered, followed by TL after 15 s.

In subsequent sessions, a VI contingency was in effect during TL such that $\overline{\text{TL}}$ was presented upon the first response after a length of time determined by the VI. The VI value was increased over sessions, from 15 to 22, 30, 45, and 60 s. These durations were determined with the same method used for the interval durations of the VI in the multiple schedule. $\overline{\text{TL}}$ components lasted for approximately twice the DRO value, regardless of whether any pellets had been delivered, and were determined as for the component durations in the multiple schedule.

The chain VI DRO schedule used by Weiss et al. (1993a) was modified to make the delivery of food more variable, so that the change in contingencies when the stimulus-element test was performed in extinction would be minimized. If pellets were delivered every time a fixed-length DRO requirement was satisfied (as in the earlier study), this temporal regularity would have contrasted sharply with the

extinction imposed during the test. The addition of variability to the DRO component also made it more comparable to the VI component of the mult VI EXT schedule, in which food was delivered at irregular intervals and approximately 15% of the VI components passed without food (when the interval exceeded the component length). According to the modified DRO schedule, a pellet was delivered with a probability of .5 when a timer (set to half the nominal DRO value) was satisfied. The timer was reset when it reached zero, when a response occurred, and at the beginning of the component. The DRO value was gradually increased to 30 s, and once the DRO 30-s schedule had been in effect for approximately three sessions, 15% of DRO components were programmed so that no pellets were delivered regardless of responding. Non-reinforcement in $\overline{\text{TL}}$ components was never scheduled for more than three consecutive components.

Stimulus-element test. The training criteria and testing procedures for mult VI EXT and chain VI DRO were the same. After the final parameters of a training schedule were reached, a rat was required to respond in TL at a rate at least 10 times higher than in $\overline{\text{TL}}$ for five consecutive sessions. In addition, during these sessions responding had to start promptly when TL was presented and cease abruptly when TL was removed, as indicated by the cumulative record.

Once the training criteria were met, a stimulus-element test was administered during the next session. Prior to the test, there was a warm-up period (approximately 30 min) during which the training schedule was in effect. During the test, food delivery was terminated (extinction). Twelve 1-min presentations of tone, light, and TL were made during the test, with each test stimulus separated by a 1-min $\overline{\text{TL}}$ presentation. The order in which the test stimuli were presented consisted of 12 randomized blocks, with each stimulus (tone, light, and TL) occurring once in each block.

Reversal procedure. Each rat was originally trained under one of the two schedules described above, tested, then trained under the other schedule and tested again. Nine rats received chain VI DRO training first, and 5 received mult VI EXT training first. All were reversed to the other schedule in the session following their first element test. When re-

versing from chain VI DRO to mult VI EXT, reversal training began with mult CRF EXT and progressed as for the rats originally trained under mult VI EXT. When reversing from mult VI EXT to chain VI DRO, the rats were placed on chain CRF DRO 3 s. However, if these rats did not respond at a rate of at least two responses per minute during the first 20 min of a session, the magazine-training/shaping procedure for the chain VI DRO schedule (described above) was instituted. Training for this group progressed as described for sessions following magazine-training/shaping sessions for the rats originally trained under chain VI DRO. The training criteria and stimulus-element test for the reversal schedules were the same as for the original training schedules.

RESULTS AND DISCUSSION

Reversal Training

Response rates during the final 5 (criterion) days of training under the original schedules are presented in the left panels of Figures 1 and 2. With few exceptions, the response rates and amounts of training were similar for both schedules. The details of the cumulative records were also similar for both schedules, with responding occurring at a stable rate when TL was presented and ceasing abruptly when $\overline{\text{TL}}$ was presented. Cumulative records like those generated in the present study were presented by Weiss et al. (1993a).

The numbers of training sessions required to reach the discrimination criterion were about equal under the original and reversal schedules (see numbers in parentheses in Figures 1 and 2). The right panels of Figures 1 and 2 show response rates during the final training sessions with the reversed schedules. There was a tendency for the response rates during these criterion sessions to be higher under mult VI EXT, especially in Rats L14 and L27. However, within subjects, this difference was minimal in Rats L1, L2, and L26, and Rat L6 responded at a higher rate under chain VI DRO. It should be noted that, although this difference in rates existed here, it did not in an earlier experiment in which mult VI EXT and chain VI DRO produced selective associations (Weiss et al., 1993a).

During the criterion sessions, rates of reinforcement during TL were higher under the chain VI DRO schedule (see values indicated

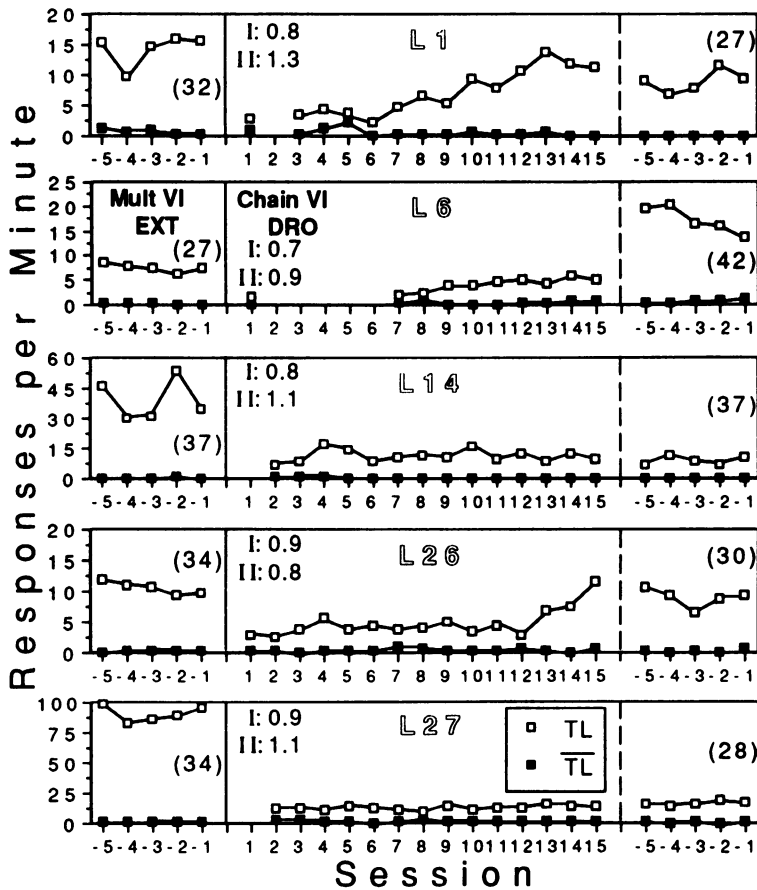


Fig. 1. Training data for for rats trained with mult VI EXT first. Response rates (responses per minute) in the presence (TL, open squares) and absence ($\overline{\text{TL}}$, filled squares) of tone and light, reinforcement rates (pellets per minute), and total numbers of sessions during mult VI EXT and chain VI DRO training are indicated. Numbers in parentheses indicate total number of training sessions under the schedule. The left panels present the mult VI EXT response rates during the last five sessions before the first element test. For chain VI DRO, response rates are presented from the first 15 sessions (center panels) after the mult VI EXT element test and the last five sessions (right panels) before the chain VI DRO element test. During sessions for which no response rates are presented, the magazine-training/shaping procedure for the chain VI DRO schedule was used. Roman numerals identify the reinforcement rates during the component in which food was delivered (TL for mult VI EXT and $\overline{\text{TL}}$ for chain VI DRO) during the final five sessions of the mult VI EXT (I) and chain VI DRO (II) phases.

by Roman numerals in Figures 1 and 2). The reinforcement rates under a given schedule were consistent both within and between groups, with one exception. The rate under chain VI DRO was lower and more variable when rats were switched from mult VI EXT to chain VI DRO than when chain VI DRO was the original training schedule. The rein-

Fig. 2. Training data for rats trained with chain VI DRO first. Response rates (responses per minute) in TL (open squares) and $\overline{\text{TL}}$ (filled squares), reinforcement rates (pellets per minute), and total numbers of sessions (in parentheses) during chain VI DRO and mult VI EXT training are shown. The left panels present response rates during the last five sessions of chain VI DRO training before the first element test. For mult VI EXT, response rates during the first 15 sessions (center panels) after the chain VI DRO element test and the last five sessions (right panels) before the mult VI EXT element test are presented. Roman numerals identify the reinforcement rates during the component in which food was delivered (TL for mult VI EXT and $\overline{\text{TL}}$ for chain VI DRO) during the final five sessions of the chain VI DRO (I) and mult VI EXT (II) phases.

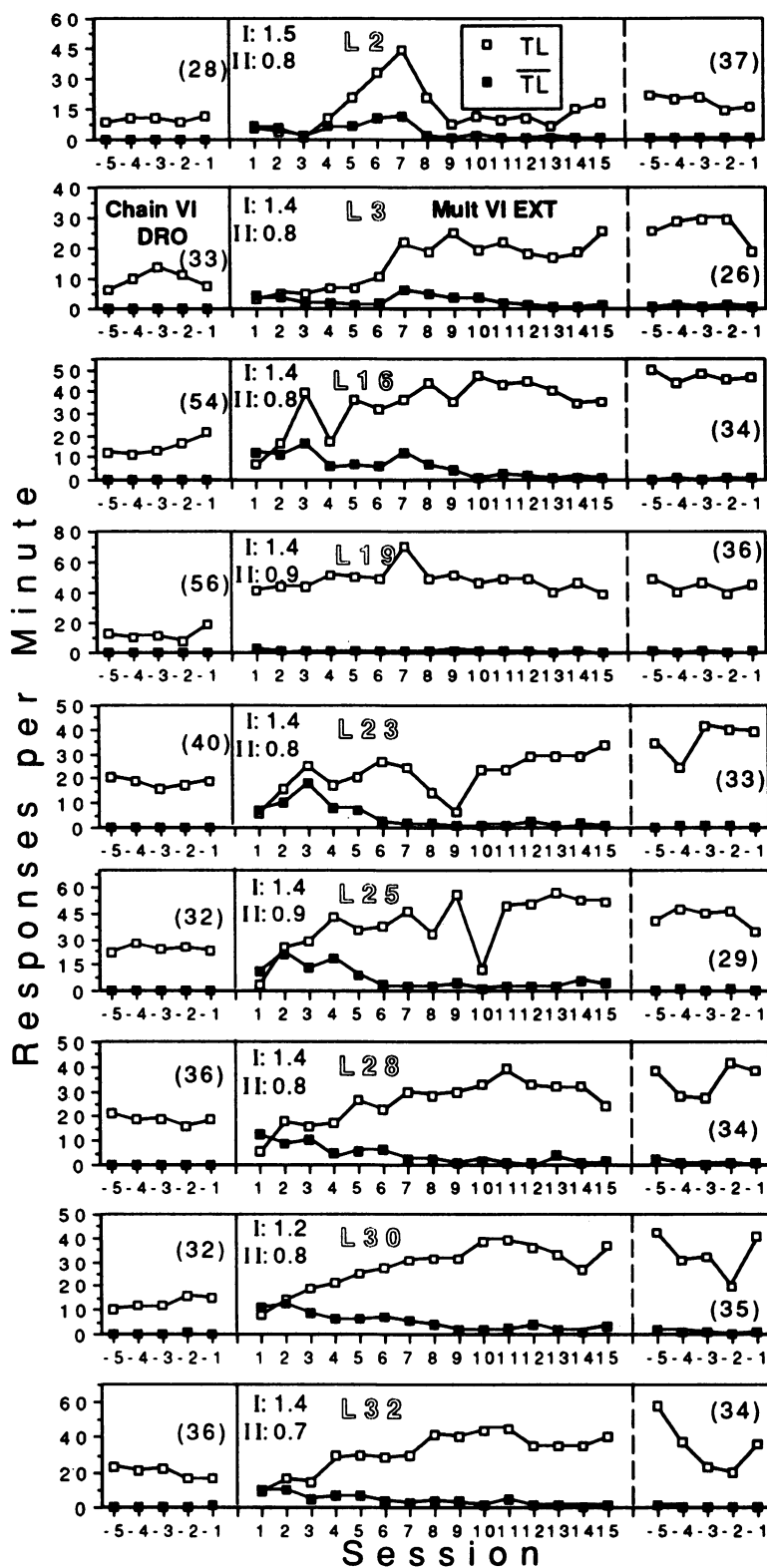


Table 1

Response rates (in responses per minute) in the presence of tone (T), light (L), tone + light (TL), and absence of tone and light (\overline{TL}) during stimulus-element tests following mult VI EXT and chain VI DRO training for groups of rats trained with mult VI EXT or chain VI DRO first.

Subject	Chain VI DRO				Mult VI EXT			
	T	L	TL	\overline{TL}	T	L	TL	\overline{TL}
Mult VI EXT first								
L1	4.6	3.2	6.5	2.6	0.8	3.2	7.2	0.1
L6	7.1	8.0	8.3	2.0	0.5	1.4	11.7	0.0
L14	4.0	4.3	5.2	0.6	0.4	0.7	5.2	0.0
L26	6.0	3.0	5.0	0.9	0.4	1.4	6.2	0.1
L27	8.4	5.8	13.2	1.9	7.3	9.4	56.4	0.6
M	6.0	4.9	7.6	1.6	1.9	3.2	17.3	0.1
Chain VI DRO first								
L2	1.7	2.3	3.4	1.1	1.7	0.4	12.3	0.3
L3	2.4	2.7	2.8	2.8	0.2	1.8	4.5	0.1
L16	1.9	1.6	3.7	0.5	9.0	11.6	69.8	0.4
L19	1.1	4.5	7.7	0.6	0.6	3.1	7.1	0.1
L23	6.2	9.8	9.2	1.6	1.3	7.5	40.2	0.4
L25	11.6	10.1	9.6	1.3	0.3	7.3	42.7	0.2
L28	9.5	10.4	13.3	4.8	0.1	7.1	25.4	0.1
L30	3.5	2.1	4.7	1.6	1.5	1.1	28.4	0.1
L32	5.8	4.8	6.4	2.7	0.9	1.0	3.7	0.1
M	4.9	5.4	6.7	1.9	1.7	4.6	26.0	0.2

forcement rate was made greater under chain VI DRO to increase response rates, but a balance had to be struck between keeping the response rates and the reinforcement rates as similar as possible to the mult VI EXT condition. Previously, similar response rates were obtained between mult VI EXT and chain VI DRO groups by programming a higher reinforcement rate under chain VI DRO (Weiss et al., 1993a). In the present experiment, because the chain VI DRO schedule was modified by increasing the temporal variability of food presentation, the relatively higher rate of reinforcement did not produce response rates as high as those of the mult VI EXT schedule. However, in all cases, food was presented during only one component of each schedule. This all-versus-none difference between components of a given schedule would presumably have a greater effect on the modality of stimulus control than the relatively minor difference in reinforcement rates between the two schedules.

Clear behavioral differences were observed between the groups during the transitions between schedules. When rats were first switched from mult VI EXT to chain VI DRO, TL responding decreased (see Figure 1, center

panels). Most of the rats in this group required exposure to the magazine-training/shaping procedure to increase responding under the new schedule (as indicated by sessions for which no response rates are presented in the center panels of Figure 1). During \overline{TL} , this group's response rates continued to be close to zero when the schedule was reversed. Thus, the main objective of reversal training for this group was to increase the response rates during TL.

In contrast, when rats were first switched from chain VI DRO to mult VI EXT, decreases in TL responding were less extreme (see Figure 2, center panels), and the magazine-training/shaping procedure was not necessary. Furthermore, responding during \overline{TL} increased initially and only decreased gradually over sessions. The objectives of reversal training for this group, therefore, were to increase responding during TL and to decrease responding during \overline{TL} .

Stimulus-Element Tests

The appetitive selective association effect was completely reversible, and the results of all subjects were consistent. During both stimulus-element tests, light clearly controlled the responding of rats trained under mult VI EXT,

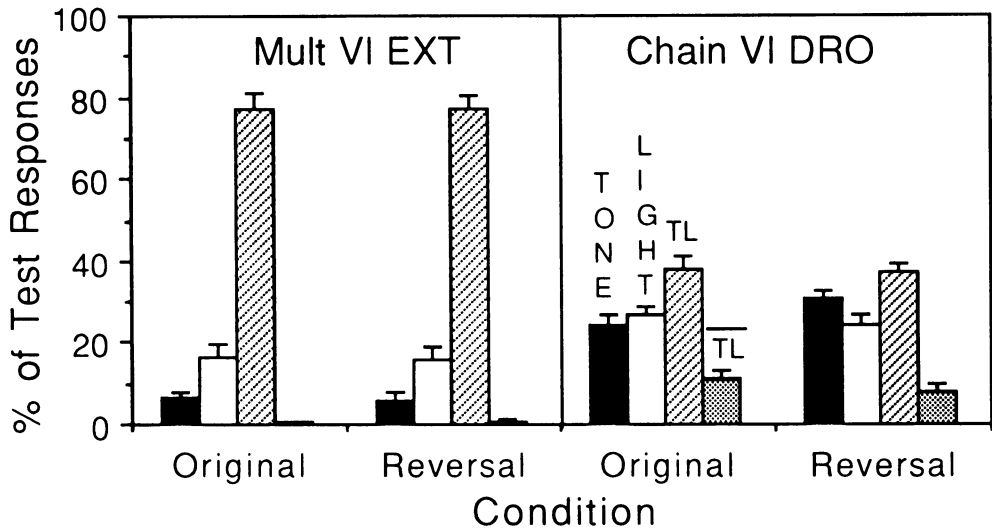


Fig. 3. Group mean response rates ($\pm SEM$) in the presence of tone, light, TL, and \overline{TL} during stimulus element tests after mult VI EXT (left panel) and chain VI DRO training (right panel) for each group. Each response rate was expressed as a percentage of the sum of all four rates for each rat, then included in the group average. Within each panel, the results of the group originally trained under the schedule are presented on the left, and the results of the group for which the schedule was the reversal condition are on the right.

and tone and light controlled comparable rates after chain VI DRO training (see Table 1). The results of each group during the first and second tests are presented in Figure 3, where the response rate for each test stimulus is expressed as a percentage to adjust for individual differences in overall rate. In both the original and reversal tests, the visual superiority under mult VI EXT contrasted with the considerable auditory control produced by the chain VI DRO schedule. The patterns of test responding were clearly determined by the schedule of reinforcement in effect prior to testing, regardless of which schedule had been trained first.

The percentage of element responses in the presence of light for each rat is presented in Figure 4. Response rates in light (L) were expressed as a percentage of the sum of the rates in tone (T) and light, according to the formula $100 \times L/(T + L)$. This value represents the amount of control exerted by light relative to tone. The mean percentage of element responses in light was 71.2% for the rats originally trained with mult VI EXT and 72.9% for rats trained with mult VI EXT as the reversal condition. These percentages were 52.7% and 44.2% for the original and reversal chain VI DRO conditions, respectively. Thus, the relative effectiveness of tone and light was

determined by the training schedule, with the visual element dominant over the auditory under mult VI EXT and about equal under chain VI DRO. Repeated measures ANOVA confirmed that the percentage of element responses to light was significantly different under the two schedules, $F(1, 12) = 29.853$, $p < .0001$. The effect of training order, $F(1, 12) = 1.336$, $p > .27$, and the order \times schedule interaction, $F(1, 12) = 0.109$, $p > .74$, were not statistically significant.

The consistency with which the training effects were reversible is seen most clearly in Figure 4. Every rat showed stronger visual control after training with mult VI EXT than after chain VI DRO, irrespective of training order. As in the original demonstration of the stimulus-reinforcer interaction with rats (Schindler & Weiss, 1982), the control under mult VI EXT was strongly visual. Under chain VI DRO, tone gained considerable control, but not all subjects showed true auditory superiority (i.e., less than 50% element responses to light in Figure 4). This control by both tone and light in the chain VI DRO group was quite similar to that seen after shock-avoidance training in the original experiment of Schindler and Weiss.

As in an earlier experiment comparing these two schedules (Weiss et al., 1993a), chain VI

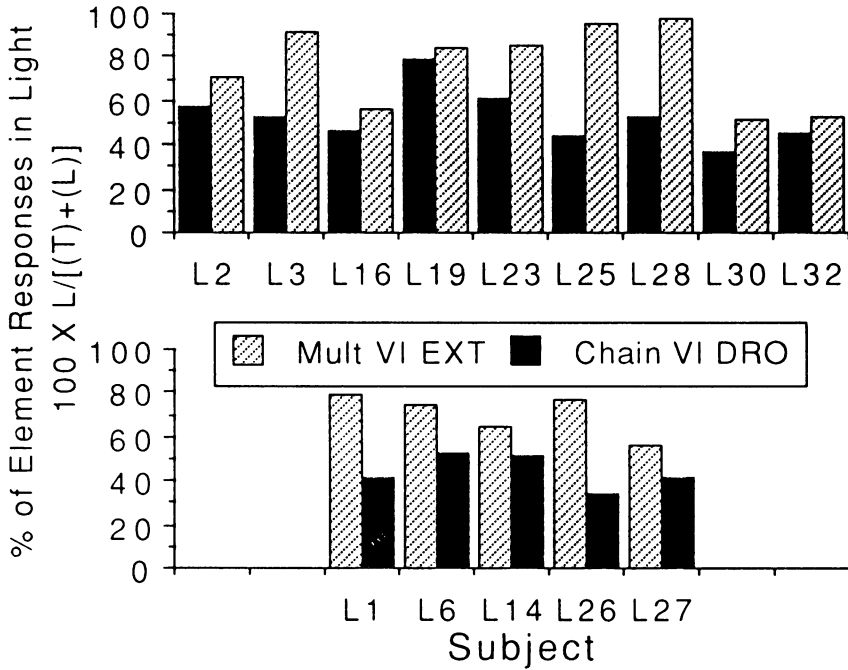


Fig. 4. Response rates of individual subjects in the presence of light, expressed as percentage of the sum of response rates during the tone (T) and light (L) elements, using the formula $100 \times L / (T + L)$, under mult VI EXT and chain VI DRO. Subjects in the upper panel were trained with chain VI DRO first, and subjects in the lower panel were trained with mult VI EXT first.

DRO training tended to produce more responding during \overline{TL} presentations than did mult VI EXT. This difference was statistically significant for the data presented in Figure 3, $t(13) = 5.862$, $p < .0001$. Modifications of the DRO schedule (described above) were not completely successful in eliminating this disruption. However, all rats except L3 maintained the TL versus \overline{TL} discrimination during the test. Furthermore, analyses of earlier data (Weiss et al., 1993a, 1993b) determined that responding during \overline{TL} intertrial intervals had no consistent effect on responding during tone, light, and TL presentations.

A striking feature of the data in Figure 3 is the strong configural effect (Rescorla, 1973) produced by mult VI EXT training, in which responding controlled by the original training stimulus (TL) was greater than the sum of responding to its elements, a result that was also seen earlier (Schindler & Weiss, 1982). Of the schedules we have studied with rats, chain VI DRO has been the only one that has not produced this effect, and it has even produced greater response rates in the presence of the tone than in the presence of the com-

pound stimulus for some rats (Weiss et al., 1993a). The lack of a strong configural effect is probably related to the fact that the discriminative stimulus is associated with a decrease in reinforcer probability on the chain VI DRO schedule, a situation that reduces additive summation in the stimulus compounding paradigm (Weiss, 1978). However, the presence or absence of a configural effect (which relates the elements to the compound) is independent of the selective association effect (which relates the elements to each other) and cannot be viewed as an explanation of the appetitive selective association.

EXPERIMENT 2

In Experiment 1, an appetitive selective association was demonstrated using a within-subject design. The modality of stimulus control was determined by the schedule trained most recently, regardless of the rat's previous history. Experiment 2 evaluated the within-subject reversibility of an aversive selective association effect using rats that had previously demonstrated the effect in an experiment using

an independent-groups design (Weiss et al., 1993b). Like the food schedules of Experiment 1, the shock schedules used in this demonstration were designed to condition opposite hedonic values to the TL discriminative stimulus. In both shock schedules, rats avoided shock in TL according to the same free-operant-avoidance contingency. In one schedule, no shocks were delivered in TL, making it a multiple free-operant-avoidance extinction schedule (mult FOA EXT), with "extinction" referring to the absence of shock. In the other schedule, both response-independent shock and response-produced shock were presented during TL components, making it a multiple free-operant-avoidance noncontingent-shock-plus-punishment schedule (mult FOA NCS+PUN). According to a hedonic analysis, TL (avoidance) should have been more aversive than TL (extinction) under the mult FOA EXT schedule. Under mult FOA NCS+PUN, however, the difference in hedonic value between TL and TL would have been reduced because shock was delivered in both components, and TL could even have become a positive conditioned reinforcer because shock was avoidable in its presence but not in its absence. Furthermore, shock delivery was "signaled" temporally in TL (i.e., it always occurred 25 s after a response; see Anger, 1963) and not in TL, which could also have made TL a conditioned reinforcer (Hiraoka & Ishikawa, 1990). Thus, the hedonic hypothesis was supported when mult FOA EXT produced predominantly auditory stimulus control, but mult FOA NCS+PUN training produced visual control even more extreme than that produced by training with a mult VI EXT food schedule.

In the previous reversibility experiments (Experiment 1, above, and Experiment 2 of Schindler & Weiss, 1982), different contingencies operated during TL in the schedules compared. In contrast, the same free-operant-avoidance contingency operated in the TL component of the two schedules of Experiment 2. As in Experiment 1, even though these schedules clearly produced divergent results with naive rats, it could not be assumed that further training could reverse the sensory dominance of stimulus control already established in an earlier phase of training. Although the robust visual control produced by mult FOA NCS+PUN might be expected to be capable

of reversing auditory control originally produced by mult FOA EXT, the visual control produced by mult FOA NCS+PUN might be expected to resist modification by reversal training with mult FOA EXT. Previously observed aversive-conditioning phenomena also suggest that a reversal of the effects of mult FOA NCS+PUN would be difficult. Weiss and Schindler (1985) found that when shock was no longer associated with an aversive discriminative stimulus, even though avoidance responding ceased in its presence, the stimulus still retained aversive properties. When the stimulus was presented in combination with a stimulus currently discriminative for avoidance, it did not decrease responding, as it would if it had always been associated with the absence of shock (Weiss, 1978). In a related experiment (Coulter & Weiss, 1971) using a conditioned-suppression procedure, a stimulus was originally associated with shock, then was presented without shock until it no longer suppressed food-maintained responding (and actually controlled increased responding in 3 of 4 rats). When this stimulus was compounded with a stimulus that had been consistently associated with shock, it did not reduce suppression, as it would if it had consistently been associated with the absence of shock. In short, presenting a previously shock-associated stimulus without shock was not sufficient to make it equivalent to a stimulus never associated with shock. This suggested that training with mult FOA EXT would not produce the same results with rats previously given mult FOA NCS+PUN training as it does with naive rats. However, the reversibility of the stimulus-reinforcer and appetitive selective association effects suggested that the aversive selective association effect should also be reversible.

METHOD

Subjects

Ten rats were trained concurrently with the rats of Experiment 1. The results of the first phase of training, prior to schedule reversal, were presented as group data by Weiss et al. (1993b). Two rats were dropped when they failed to make progress during the avoidance training phase of Experiment 2. The remaining rats were divided into two groups of 4. All rats were kept at 80% of ad lib weights to maintain comparability with the food-trained

rats of Experiment 1 and with rats in other selective association experiments performed in this laboratory.

Apparatus

The apparatus was the same as that of Experiment 1. Scrambled electric shocks of 0.5 s were generated by oil-bath shockers (LVE 113-04) and were delivered through stainless-steel rods that comprised the chamber floor.

Procedure

Rats on shock schedules were trained on alternate days. First, lever pressing was shaped by successive approximation, with TL present throughout the session. Responding terminated a continuous 0.5-mA shock. Once escape responding was established, a free-operant-avoidance schedule was instituted. During the first session of FOA training, each response postponed shock delivery by 25 s—the response-shock (RS) interval. Once 25 s had passed without a response, the shock-shock (SS) interval was entered, and shock was delivered every 2 s until a response occurred. Thus, the parameters were RS 25 s SS 2 s. Over the next few sessions, the SS interval was increased to 5 s. The RS interval was not changed. The parameters of the FOA schedule remained RS 25 s SS 5 s for the remainder of the experiment. Shocks were scheduled to last 0.5 s, but responses that occurred during a shock prolonged it, so that shock was not terminated until 0.5 s had passed without a response. This contingency was intended to promote avoidance (as opposed to escape) by preventing shock-prompted responses from being immediately followed by shock termination. Early in training, sessions lasted until approximately 200 shocks had been delivered. When reliable shock avoidance developed, session length was increased to 8 hr. Shock intensity (ranging between 0.6 and 1.8 mA) was adjusted for individual rats so that it was no higher than necessary to maintain stable rates of avoidance.

The FOA schedule, with TL present throughout each session, was continued until a rat met an avoidance criterion of less than 0.6 shocks per minute (at which rate approximately 75% of scheduled RS shocks were avoided) for five consecutive sessions. When this criterion had been met, discrimination training began, with 4 rats receiving mult FOA

EXT training first and 4 receiving mult FOA NCS+PUN first. Discrimination training consisted of alternating TL and $\overline{\text{TL}}$ components. The component durations were drawn randomly and without replacement from a list that ranged from 60 to 200 s, with a mean of 129 s. The first 30 min of each discrimination training session were considered a warm-up period, and the data from this period were not analyzed.

Original training under mult FOA EXT. During TL, FOA was in effect, and during $\overline{\text{TL}}$, responding had no scheduled consequences. Training continued until, for three consecutive sessions, a rat (a) responded 10 times faster in TL than $\overline{\text{TL}}$, (b) received 0.6 shocks per minute or less during TL, and (c) responded prior to a shock being delivered (i.e., within the first 25 s of the component) in at least 75% of the TL components.

Testing occurred during the first session after these training criteria had been met. After approximately 3 hr of warm-up training, the stimulus-element test was administered in extinction. This test was identical to the one used in Experiment 1, except that there were two reacquisition periods to increase the number of responses emitted during the test. During a reacquisition period, there was one component of FOA in the presence of TL followed by an extinction period in $\overline{\text{TL}}$. Reacquisition periods were balanced so that T, L, and $\overline{\text{TL}}$ were each presented once following either the warm-up or a reacquisition period. Rat L5 emitted no responses in the first test during the mult FOA EXT phase. Therefore, L5 was retrained under mult FOA EXT with a 10-s RS interval, which increased the baseline response rate. L5 was then retested before advancing to the schedule reversal phase.

Original training under mult FOA NCS+PUN. After meeting the 0.6 shocks per minute avoidance criterion under the simple FOA schedule, mult FOA NCS training began (without the punishment contingency). Like the mult FOA EXT schedule, the FOA schedule was in effect during TL. However, during $\overline{\text{TL}}$, noncontingent shock was delivered according to a VT schedule at a rate approximately equal to that in the avoidance component (TL) of the previous session. During the initial sessions with NCS, responding during TL had no effect.

After three to five sessions of training with

only noncontingent shock in $\overline{\text{TL}}$, a punishment contingency was added to the $\overline{\text{TL}}$ component, wherein each response produced a 0.5-s shock. This procedure was necessary to reduce responding during $\overline{\text{TL}}$ (as described below). After these rats satisfied the same discrimination criteria described for the mult FOA EXT schedule, the same stimulus-element test was given, with the addition of two noncontingent shocks delivered during the first $\overline{\text{TL}}$ reacquisition component and one during the second. Although the punishment contingency was also included during $\overline{\text{TL}}$ reacquisition periods, no responses were emitted.

Reversal procedure. After the 4 rats originally trained under mult FOA EXT were tested, they were switched to mult FOA NCS+PUN and tested again. After the 4 rats originally trained under mult FOA NCS+PUN were tested, they were trained under mult FOA EXT and tested again. Discrimination training under the reversal schedules was the same as that described for the same schedules used as initial training conditions, except for the number of sessions prior to the institution of punishment in the group reversed to mult FOA NCS. An attempt was made to train the discrimination without the punishment contingency, but the response rates during $\overline{\text{TL}}$ did not drop and the discrimination criterion was not met. Therefore, punishment was instituted after approximately 25 sessions with only NCS in $\overline{\text{TL}}$, and training continued as for the rats originally trained under mult FOA NCS+PUN.

RESULTS AND DISCUSSION

Reversal Training

Figures 5 and 6 show TL and $\overline{\text{TL}}$ response rates during all discrimination training sessions under the original and reversed schedules for each rat (except L5; see below). The discrimination criterion was quickly met by the rats originally trained under the mult FOA EXT schedule (Figure 5, left panels). The rats originally trained under mult FOA NCS+PUN met criterion soon after the punishment contingency was added to the $\overline{\text{TL}}$ component (Figure 6, center panels). The response rates prior to testing were comparable both within subjects and across groups for both training schedules, with the exception of L5, which was retrained with a 10-s RS interval under mult

FOA EXT. Note that in Figures 5 and 6, even when a rat met the 10:1 discrimination criterion for three consecutive sessions, it was not tested unless it also met the 0.6 shocks per minute shock-rate criterion and responded within the first 25 s (i.e., prior to being shocked) of 75% of the TL components of each session.

The rats originally trained under mult FOA NCS+PUN continued to meet the discrimination criterion when the $\overline{\text{TL}}$ contingency in their schedule was switched from noncontingent shock plus punishment to extinction (i.e., when delivery of shocks in $\overline{\text{TL}}$ was terminated). Although the training criteria were met by this group almost immediately, the mult FOA EXT phase was continued for 3 to 4 weeks to allow a generous amount of time for the new schedule to have effects.

Before the punishment contingency was added, rats in both groups responded at substantial rates during the noncontingent-shock component (see Figure 5, center panels; Figure 6, left panels). This mult FOA NCS phase was continued for at least 25 sessions for the rats originally trained under mult FOA EXT to determine whether the discrimination criterion could be met without the punishment contingency. However, noncontingent shock maintained substantial response rates even when responding during $\overline{\text{TL}}$ had essentially been eliminated during mult FOA EXT training in the previous phase (Figure 5, left panels). The baseline performances did not progress towards the discrimination criterion until punishment was instituted. In contrast, during the first session in which $\overline{\text{TL}}$ responses were punished, responding in this component decreased dramatically (Figure 5, right panels; Figure 6, center panels). In fact, the high rate of shock in $\overline{\text{TL}}$ during the first 30 min under the punishment contingency ($M = 2.08$ shocks per minute, $SEM = 0.45$) was reduced substantially during the remainder of the session ($M = 0.45$ shocks per minute, $SEM = 0.08$).

Stimulus-Element Tests

As in Experiment 1, the dominant sensory modality of stimulus control was determined by the most recently trained schedule. Mult FOA NCS+PUN produced visual stimulus control almost exclusively, whereas mult FOA EXT produced predominantly auditory control (see Figure 7). Individual subjects showed results consistent with the group patterns in

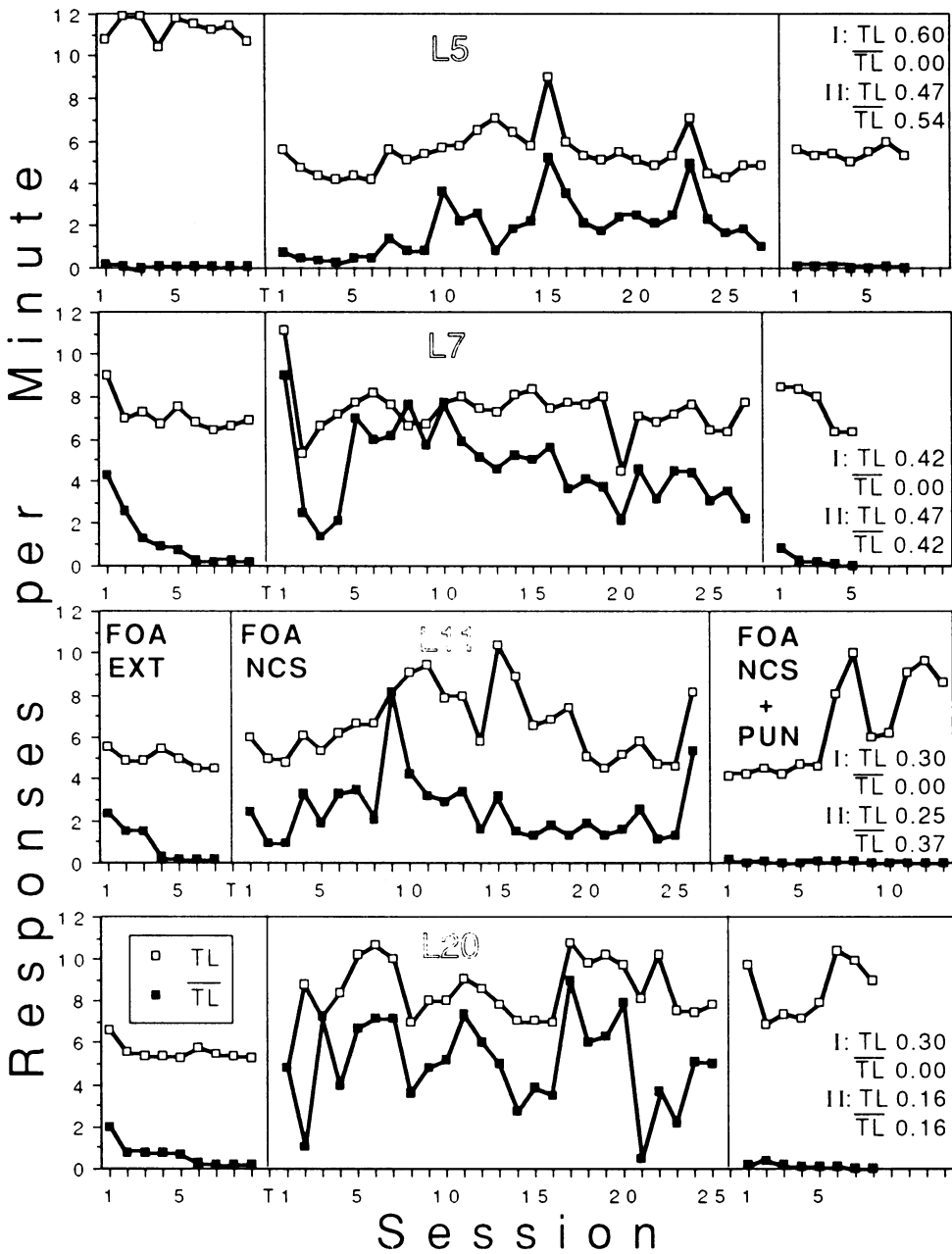


Fig. 5. Training data for rats trained with mult FOA EXT first. Shown are response rates (responses per minute) during TL (open squares) and $\overline{\text{TL}}$ (filled squares) during all training sessions with mult FOA EXT (left panels), mult FOA NCS prior to institution of the punishment contingency (center panels), and mult FOA NCS with punishment added (FOA NCS+PUN, right panels). At the point marked "T" on the horizontal axis, an element test was performed. Following training with mult FOA NCS with punishment, another test was performed. Roman numerals identify shock rates (shocks per minute) in TL and $\overline{\text{TL}}$ during the final three sessions under mult FOA EXT (I) and mult FOA NCS+PUN (II).

every case (see Table 2). The percentage of element responses to light, a direct measure of the relative strength of visual control, was higher after mult FOA NCS+PUN training

(92.8% and 90.3% under the original and reversal conditions, respectively) than after mult FOA EXT (27.3% and 24.2% under the original and reversal mult FOA EXT conditions,

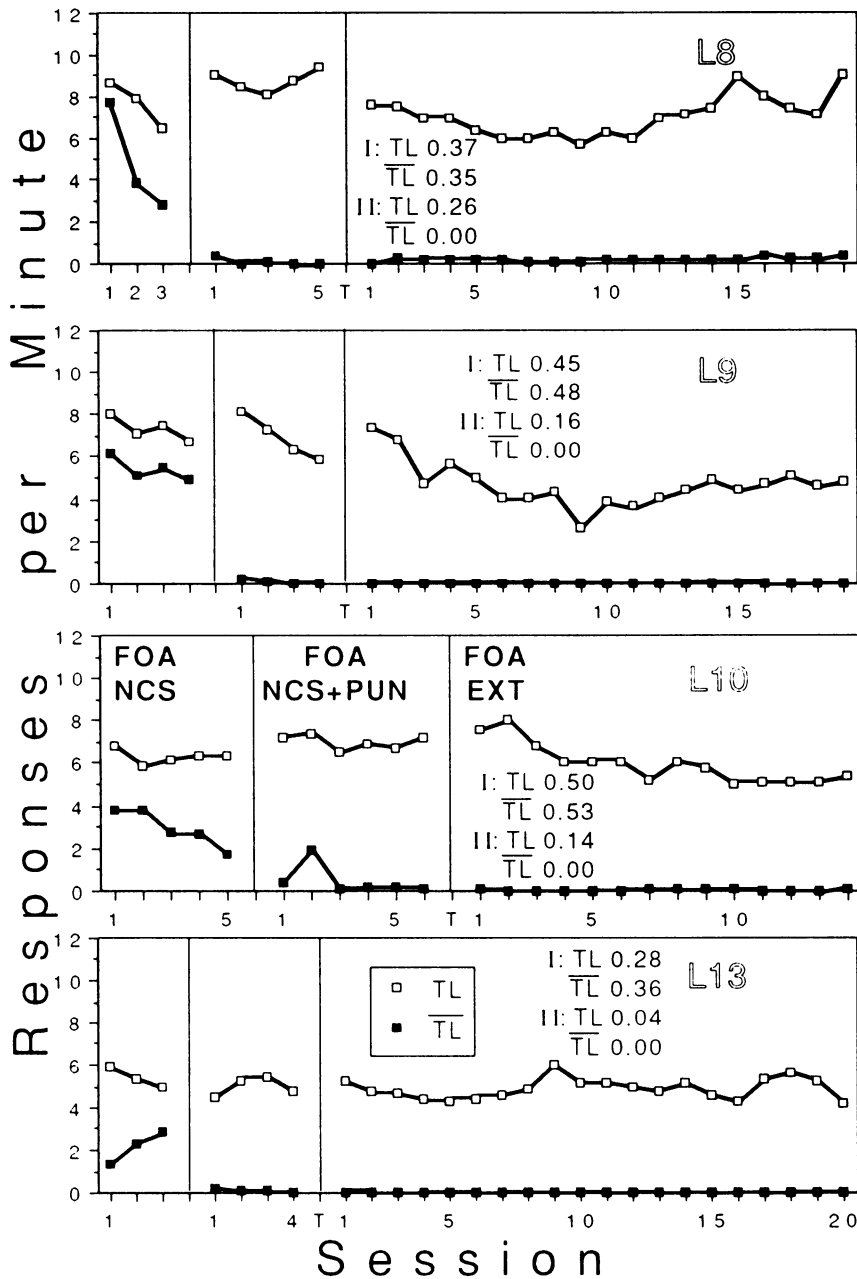


Fig. 6. Training data for rats trained with mult FOA NCS+PUN first. Shown are response rates (responses per minute) during TL (open squares) and TL (filled squares) during all training sessions with mult FOA NCS without the punishment contingency (left panels), mult FOA NCS with responses punished during TL (FOA NCS+PUN, center panels), and mult FOA EXT (right panels). At the point marked "T," an element test was performed. Following training with mult FOA EXT, another test was performed. Roman numerals identify shock rates (shocks per minute) in TL and TL during the final three sessions under mult FOA NCS+PUN (I) and mult FOA EXT (II).

respectively), a statistically significant difference across conditions, $F(1, 6) = 76.295$, $p < .0001$. The order of training, $F(1, 6) = 0.092$, $p > .75$, and the schedule \times order interaction,

$F(1, 6) = 0.022$, $p > .85$, were not statistically significant for this measure. The results under mult FOA NCS+PUN were apparently unaffected by prolonging NCS training prior to

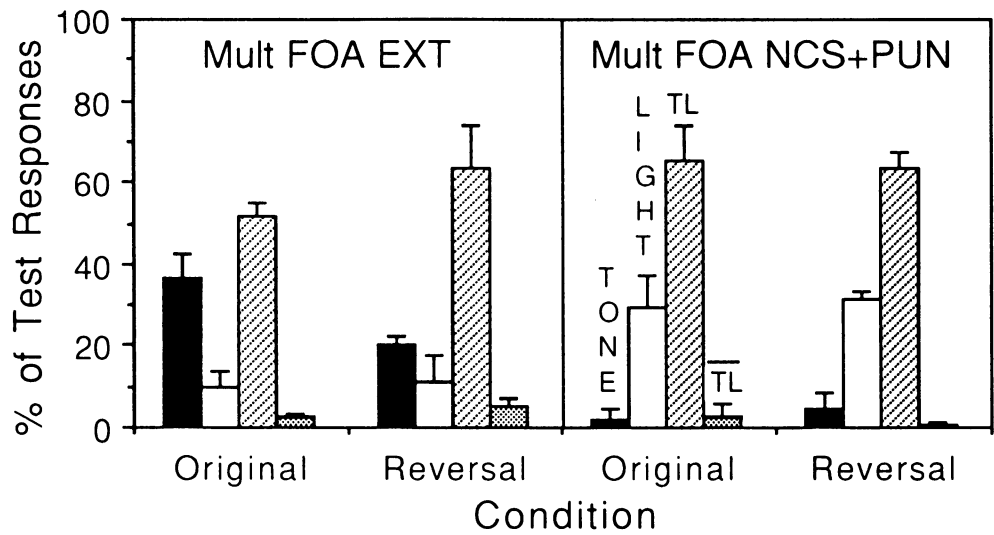


Fig. 7. Stimulus-element test response rates ($M \pm SEM$), expressed as percentages, after mult FOA EXT (left panel) and mult FOA NCS+PUN training (right panel) for each group. Each response rate was expressed as a percentage of the sum of all four rates for each rat, then included in the group average. Within each panel, the results of the group originally trained under the schedule are presented on the left, and the results of the group for which the schedule was the reversal condition are on the right.

the institution of the punishment contingency when mult FOA NCS+PUN was the reversal schedule.

In four of the eight tests following mult FOA NCS+PUN training and three of the eight tests following mult FOA EXT training, *exclusive* control by the dominant stimulus element was seen (see Table 2). Yet, when the nondominant element was presented as part

of the compound stimulus, responding occurred at a higher rate than during the dominant element alone. The magnitude of this configural effect was similar after all phases of training, although it was slightly smaller when mult FOA NCS+PUN was the original training condition (see Figure 7).

Figure 8 summarizes the results of experiments demonstrating the reversibility of selec-

Table 2

Response rates (in responses per minute) in the presence of tone (T), light (L), tone + light (TL), and absence of tone and light (\overline{TL}) during stimulus-element tests following mult FOA EXT and mult FOA NCS+PUN training for groups of rats trained with mult FOA EXT or mult FOA NCS+PUN first.

Subject	Mult FOA NCS+PUN				Mult FOA EXT			
	T	L	TL	\overline{TL}	T	L	TL	\overline{TL}
Mult FOA EXT first								
L5	0.1	1.5	3.3	0.0	2.3	1.3	3.6	0.3
L7	0.8	1.5	2.6	0.1	1.7	0.3	2.5	0.1
L11	0.0	2.2	5.5	0.0	1.4	0.8	3.4	0.4
L20	0.2	4.9	8.2	0.0	1.0	0.0	0.8	0.1
M	0.3	2.5	4.9	0.0	1.6	0.6	2.6	0.2
Mult FOA NCS + PUN first								
L8	0.0	3.0	5.1	0.0	3.5	3.3	7.8	0.9
L9	0.6	1.7	3.5	0.7	0.7	0.0	3.3	0.1
L10	0.0	0.3	2.3	0.0	1.2	0.0	5.2	0.1
L13	0.0	2.6	3.1	0.0	3.1	2.9	5.3	1.4
M	0.1	1.9	3.5	0.2	2.1	1.5	5.4	0.6

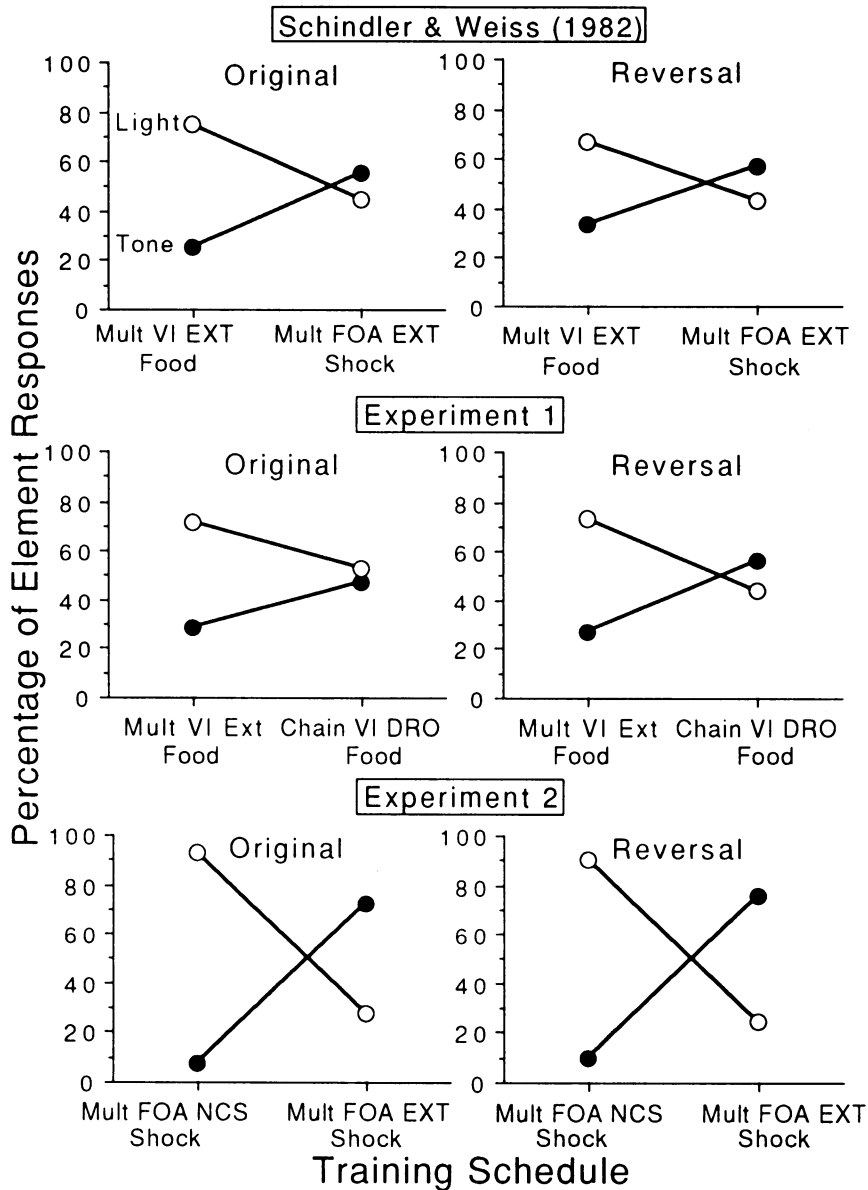


Fig. 8. Interaction profiles showing mean response rates to tone and light expressed as a percentage of total responses to tone and to light, summarizing the results of mult VI EXT and mult FOA EXT groups (Schindler & Weiss, 1982) as well as Experiments 1 and 2 of the present study. For each experiment, profiles in the left panels represent the element test results from the original training phases, and those in the right panels represent the results obtained with the same rats after training with the schedules switched.

tive associations. The top panel of Figure 8 shows the within-subject stimulus-reinforcer interaction reported by Schindler and Weiss (1982). The middle panel shows the within-subject appetitive selective association of Experiment 1, and the lower panel shows the within-subject aversive selective association of

Experiment 2. Because of the differences in apparatus and procedures, only imprecise comparisons can be made between effect sizes of different experiments. However, it is clear that the effects of all four schedules (mult FOA EXT, mult FOA NCS+PUN, mult VI EXT, and chain VI DRO) can be reversed by train-

ing with one of the other schedules, using either the same or a different reinforcer to maintain responding in TL.

GENERAL DISCUSSION

Like the stimulus–reinforcer interaction effect, both the appetitive and aversive single-incentive selective associations proved to be reversible. In Experiment 1, responding under both schedules was controlled by TL and was ultimately maintained by food. However, food was delivered only during TL under mult VI EXT and only during TL under chain VI DRO. In Experiment 2, the same FOA contingency (RS 25 s SS 5 s) maintained responding in TL under both schedules. Only the contingency operating in the absence of TL (either noncontingent shock plus punishment or extinction) differed between the shock schedules. Clearly, the contingencies maintaining responding in the presence of the discriminative stimulus must be considered in relation to those operating in its absence when seeking the dynamics responsible for selective association effects. A similar conclusion was reached when Weiss (1976, 1978) employed versions of these same schedules to isolate the discriminative and incentive factors contributing to stimulus compounding effects. In those experiments, both tone and light were trained as discriminative stimuli, and testing involved presenting them in compound. The similarities in the factors that influence these two procedures (compound training followed by element testing in the present experiment, and element training followed by compound testing in the stimulus-compounding studies) suggest that common processes are involved in selective association and stimulus-compounding effects.

The original impetus for the single-incentive manipulations of Experiments 1 and 2 came from the observation of a procedural confounding effect in the experiments reporting the stimulus–reinforcer interaction (Weiss et al., 1993a). The physical properties of the reinforcer maintaining responding (food vs. shock) covaried with the conditioned hedonic value of the TL component (positive vs. negative). Based on evidence from observing-response studies (Dinsmoor, 1983), the food schedules used by Foree and LoLordo (1973) and Schindler and Weiss (1982) involved pro-

cedures that should have conditioned positively reinforcing properties to TL (Auge, 1974; Kendall & Gibson, 1965), whereas their shock schedules involved procedures that should have conditioned punishing or aversive properties to TL (Culbertson & Badia, 1973; Hiraoka & Ishikawa, 1990). The chain VI DRO schedule was intended to break this confounding effect by making TL (where all food was received) the preferred schedule component of a food schedule, thereby conditioning negative hedonic properties to TL. The mult FOA NCS+PUN schedule was intended to make TL (where shock was avoidable) the preferred component of a shock schedule, thereby conditioning positive hedonic properties to TL. To the extent that these schedules conditioned the intended hedonic value to the TL discriminative stimulus, the powerful within-subject effects reported here support the hypothesis that the conditioned hedonic value of TL contributes to the determination of the sensory nature of stimulus control. A stronger conclusion requires measuring the conditioned reinforcing value of TL at either the time when the discrimination forms or when the stimulus–element test is administered.

Consideration of a case in which selective associations were not obtained might help define the conditions necessary for a reversal of preestablished sensory dominance. When Schindler and Weiss (1985; cf. LoLordo et al., 1982) used single-element training prior to training with TL in the stimulus–reinforcer interaction procedure, blocking occurred. That is, pretraining with tone as the discriminative stimulus in mult VI EXT prevented visual control from developing, and pretraining with light in mult FOA EXT prevented auditory control from developing under subsequent compound-stimulus (TL) training. Thus, when the contingency did not change, the addition of a stimulus “favored” by the contingency was not sufficient to reverse the preestablished modality of control.

In traditional blocking studies, a stimulus presented in compound with an established conditioned or discriminative stimulus tends to gain control only when its appearance is associated with a change in the value of the reinforcer (Dickinson, Hall, & Mackintosh, 1976; Kamin, 1969; Mackintosh, Bygrave, & Picton, 1977; Rescorla, 1971). Thus, es-

pecially in Experiment 2, in which the TL was associated with the same avoidance contingency under both the mult FOA EXT and mult FOA NCS+PUN schedules, blocking might have been predicted in the present experiments. However, removing the correlation of TL and shock (as when mult FOA EXT was switched to mult FOA NCS+PUN) or TL and food (as when mult VI EXT was switched to chain VI DRO) is exactly the kind of manipulation that can attenuate blocking. Therefore, the principle of redundancy (Kamin, 1969) appears to determine whether training with a selective association schedule will reverse control already established to a certain modality.

In blocking and attenuation-of-blocking experiments, training occurs with a single stimulus before another stimulus is added, but in the selective association experiments, the same compound stimulus was used in all phases. However, it might be that specific schedules have effects similar to increasing or decreasing the intensity of the elements of TL (Mackintosh, 1977). For example, training with mult FOA NCS+PUN may be functionally equivalent to increasing the intensity of the light and/or decreasing the intensity of the tone. Then, when this schedule is switched to mult FOA EXT, the new schedule may emphasize the auditory elements of TL, a procedure analogous to adding a stimulus when reinforcement conditions are altered in a blocking procedure. This could mean that even when the response is the same in both phases of a selective-association-reversal procedure, if the conditions sufficient to attenuate blocking exist and the new schedule tends to produce control by another modality, a reversal may be predicted.

What has been called the stimulus-reinforcer interaction now appears to be an example of a broader category of situations in which the relative effectiveness of a stimulus of a certain modality is determined by the conditioning context in which it appears. These results clearly demonstrate that different reinforcers are not necessary to produce selective stimulus control, and they demand a more general explanation than affinities between food and visual stimuli and between shock and auditory stimuli (e.g., LoLordo, 1979). The initial evidence suggests that this explanation in-

volves the relative hedonic value conditioned to TL relative to $\overline{\text{TL}}$.

REFERENCES

- Anger, D. (1963). The role of temporal discriminations in the reinforcement of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior*, **6**, 477-506.
- Auge, R. J. (1974). Context, observing behavior, and conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, **22**, 525-533.
- Coulter, W. R., & Weiss, S. J. (1971). Suppressive summation controlled by compounding a shock-associated and shock extinguished CS. *Proceedings of the 79th Annual Convention of the American Psychological Association*, **3**, 711-712.
- Culbertson, S., & Badia, P. (1973). Choice of a terminating over a nonterminating signal in free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, **20**, 235-243.
- Dickinson, A., Hall, G., & Mackintosh, N. J. (1976). Surprise and the attenuation of blocking. *Journal of Experimental Psychology: Animal Behavior Processes*, **2**, 313-322.
- Dinsmoor, J. A. (1983). Observing and conditioned reinforcement. *Behavioral and Brain Sciences*, **6**, 693-728. (Includes commentary)
- Foree, D. D., & LoLordo, V. M. (1973). Attention in the pigeon: Differential effects of food-getting versus shock-avoidance procedures. *Journal of Comparative and Physiological Psychology*, **85**, 551-558.
- Garcia, J., & Koelling, R. A. (1966). Relation of cue to consequence in avoidance learning. *Psychonomic Science*, **4**, 123-124.
- Hiraoka, K., & Ishikawa, S. (1990). Preference for signalled shock in rats: Effects of temporal regularity of shocks with fixed or variable signal duration. *Tohoku Psychologica Folia*, **49**, 15-24.
- Kamin, L. J. (1969). Predictability, surprise, attention and conditioning. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior* (pp. 279-296). New York: Appleton-Century-Crofts.
- Kendall, S. B., & Gibson, D. A. (1965). Effects of discriminative stimulus removal on observing behavior. *The Psychological Record*, **15**, 545-551.
- LoLordo, V. M. (1979). Selective associations. In A. Dickinson & R. A. Boakes (Eds.), *Mechanisms of learning and motivation: A memorial volume to Jerzy Konorski* (pp. 367-398). Hillsdale, NJ: Erlbaum.
- LoLordo, V. M., Jacobs, W. J., & Foree, D. D. (1982). Failure to block control by a relevant stimulus. *Animal Learning & Behavior*, **10**, 183-192.
- Mackintosh, N. J. (1977). Stimulus control: Attentional factors. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 481-513). Englewood Cliffs, NJ: Prentice-Hall.
- Mackintosh, N. J., Bygrave, D. J., & Picton, B. M. B. (1977). Locus of the effect of a surprising reinforcer in the attenuation of blocking. *Quarterly Journal of Experimental Psychology*, **29**, 327-336.
- Michael, J. (1982). Distinguishing between discriminative and motivational functions of stimuli. *Journal of the Experimental Analysis of Behavior*, **37**, 149-155.

- Rescorla, R. A. (1971). Variation in the effectiveness of reinforcement and nonreinforcement following prior inhibitory conditioning. *Learning and Motivation*, **2**, 113-123.
- Rescorla, R. A. (1973). Evidence for "unique stimulus" account of configural conditioning. *Journal of Comparative and Physiological Psychology*, **85**, 331-338.
- Schindler, C. W., & Weiss, S. J. (1982). The influence of positive and negative reinforcement on selective attention in the rat. *Learning and Motivation*, **13**, 304-323.
- Schindler, C. W., & Weiss, S. J. (1985). Modification of a stimulus-reinforcer interaction by blocking. *Behavioural Processes*, **11**, 123-130.
- Weiss, S. J. (1970). An effective and economical sound attenuation chamber. *Journal of the Experimental Analysis of Behavior*, **13**, 37-39.
- Weiss, S. J. (1976). Stimulus control of free-operant avoidance: The contribution of response rate and incentive relations between multiple-schedule components. *Learning and Motivation*, **7**, 477-516.
- Weiss, S. J. (1978). Discriminated response and incentive processes in operant conditioning: A two-factor model of stimulus control. *Journal of the Experimental Analysis of Behavior*, **30**, 361-381.
- Weiss, S. J., Panlilio, L. V., & Schindler, C. W. (1993a). Selective associations produced solely with appetitive contingencies: The stimulus-reinforcer interaction revisited. *Journal of the Experimental Analysis of Behavior*, **59**, 309-322.
- Weiss, S. J., Panlilio, L. V., & Schindler, C. W. (1993b). Single-incentive selective associations produced solely as a function of compound-stimulus conditioning context. *Journal of Experimental Psychology: Animal Behavior Processes*, **19**, 284-294.
- Weiss, S. J., & Schindler, C. W. (1985). Conditioning history and inhibitory instrumental stimulus control: Independent-groups and within-subjects measures. *Animal Learning & Behavior*, **13**, 215-222.
- Weiss, S. J., & Schindler, C. W. (1989). Integrating control generated by positive and negative reinforcement on an operant baseline: Appetitive-aversive interactions. *Animal Learning & Behavior*, **17**, 433-446.

Received September 9, 1992

Final acceptance February 20, 1993